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Technical Report

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DETERIORATION OF 600-VOLT CABLE  
SHEATHS BY FLOTATION-TYPE CORROSION  
INHIBITORS

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U. S. NAVAL CIVIL ENGINEERING LABORATORY  
Port Hueneme, California

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# DETERIORATION OF 600-VOLT CABLE SHEATHS BY FLOTATION-TYPE CORROSION INHIBITORS

Y-R007-08-902

Type C Final Report

by

A. E. Hanna

## OBJECT OF TASK

To find an insulating sheath material which is resistant to the deteriorating effects of oil-base corrosion inhibitors. The material must be suitable for use as an insulating cover on the 600-volt cables used in cathodic protection systems in the ballast tanks of floating dry docks.

## ABSTRACT

Failure of cathodic protection systems has been attributed to the deterioration of sheathing of electrical conductor cables immersed in flotation-type corrosion inhibitors. Cable manufacturers and distributors were asked to recommend a sheath material for cathodic protection cables in floating dry-dock ballast tanks. Materials suggested were polyethylene, polyvinyl chloride, neoprene, and a butadiene-acrylonitrile copolymer. Quantities of cables sheathed with these materials were ordered and tested with stock cables obtained from Naval supply sources.

A butadiene-acrylonitrile copolymer was found to be superior to all others after 300 hours of immersion in typical flotation-type corrosion inhibitors. The next most resistant was the polyvinyl-chloride sheath, followed closely by a Navy stock neoprene and a homogeneous polyethylene serving as both jacket and insulation.

## INTRODUCTION

Some activities have reported the occasional failure of cathodic protection systems. This failure has been attributed to the deterioration, by the action of a flotation-type corrosion inhibitor, of the neoprene (polychloroprene) sheath materials ordinarily used on the electrical conductors. Thus, a cable-sheathing material which will not break down in such an environment becomes a necessity.

Cathodic protection systems have been installed on floating dry docks to minimize the corrosion of the exterior and interior steel surfaces. These systems are effective only on the continuously submerged portions; some other method must be employed to protect the surfaces which are never, or intermittently, in contact with the water. Exterior surfaces are easily maintained, but the painted surfaces inside a ballast tank cannot be easily repaired. High humidity in these areas promotes the early failure of the usual paint systems and the rapid corrosion of exposed steel. The difficulties in the repair or replacement of paint in these compartments led to the development of "floating coatings."

These flotation-type corrosion inhibitors are generally poured on the residual-water surface in ballast compartments and sprayed on the overhead and bulkheads above water. Raising and lowering the dry dock recoats most of the inner bulkheads with the preservative. As the floating layer is lost during normal dewatering operations, additional material is poured onto the water to maintain the layer.

In theory, the concurrent use of a cathodic protection system and a flotation-type corrosion inhibitor should effectively retard corrosion in ballast compartments. The coating would protect the bulkhead and overhead areas, and the cathodic protection system would protect the areas underneath residual ballast water. Trials of such combinations have proven relatively successful, but deterioration of the sheathing material on the electrical conductors threatens success of the cathodic protection system.

Many of the materials commonly used for cable sheaths are known to be resistant to oils that are relatively free of polar compounds. There is no evidence that these materials would also be resistant to oils that do contain polar compounds. At least one of the materials used as a flotation type of corrosion inhibitor contains cresylic acid, a polar compound known to attack many insulation and sheath materials. The Bureau of Yards and Docks requested the Laboratory to investigate available sheath materials which might withstand the deteriorating effects of flotation-type corrosion inhibitors.

Various cable manufacturers were contacted by letter; replies were received from sixteen manufacturers and distributors. Five said they could not provide a cable which would be resistant to the effects of corrosion inhibitors. Two of the five thought that polyvinyl chloride might work, and one suggested polyethylene as an alternative to polyvinyl chloride.

Of eleven other manufacturers, seven recommended a polyvinyl chloride sheath, one recommended neoprene, one suggested polyethylene, and two offered special rubber sheaths. One of the latter is a butadiene-acrylonitrile copolymer, and the other is a neoprene formulation.

## PROCEDURE

### Determining the Effect of Test Fluids

Specimens of seven different cables were tested in this study, and are referred to by the codes given in Table I. A detailed description of the test cables is given in Appendix A.

Table I. Identification of Cables

Code	Sheath Material	Source
N-1	Neoprene	Commercial
N-2	Neoprene	Navy Stock
N-3	Neoprene	Navy Stock
N-4	Neoprene	Commercial
P-1	Polyethylene	Commercial
R-1	Butadiene-Acrylonitrile	Commercial
V-1	Polyvinyl Chloride	Commercial

Duplicate cable specimens were cut and curved to a U-shape to fit upright within a covered 400-milliliter or 600-milliliter beaker. Specimen ends were sealed by dipping into a bath of molten polyethylene resin to prevent test fluids or other contaminants from coming into contact with the interfaces between the conductor and insulation and between the insulation and sheath. Before being placed in the test fluids, the samples were weighed and their diameters measured at four different points with a micrometer.

Three fluids were used in the evaluation of the sheath materials; two (fluids A and C) were flotation-type corrosion inhibitors corresponding to MIL-R-21006 (Ships) and to MIL-C-17936 (Ships) respectively, and the third (fluid B) was a petroleum oil corresponding to ASTM Oil No. 2.\* The latter test fluid was included to determine if immersion in the standard oil would provide equivalent results. The fluid previously mentioned as containing cresylic acid was selected to represent MIL-C-17936.

The beakers were filled with a test fluid to a level which covered approximately three-fourths of the length of cable specimens. A typical assembly is shown in Figure 1. Specimens were exposed to the three test fluids at ambient temperature (65 - 80 F), and at 110 F, 134 F, and 175 F. Standard laboratory ovens were used to maintain the assemblies at the desired temperatures.

The test specimens were removed from the beakers semiweekly, wiped free of oil, weighed, and their diameters measured; then the specimens were replaced in the beakers. The changes from initial diameters and weights were used in establishing the relative resistance of the insulating sheaths of the various cables to the effects of the test fluids. Figures 2 through 5 (Appendix B) show graphically the effects on diameters, and Figures 6 through 9 (Appendix C) show effects on weights.

#### Determining the Effect of Sea Water

The specimens which had been immersed in fluids A and C at room temperature and at 175 F were subsequently immersed in beakers containing sea water for an additional period at the same temperatures. At the same time, new specimens were immersed in sea water at these temperatures. No new Navy stock cable was used, since the amount of those cables supplied was sufficient only for the test fluid immersion.

The diameters, in four locations on each specimen, and the weight of each specimen were determined prior to immersion in sea water. After 95, 185, and 315 hours of immersion the specimens were removed from the sea water, dried, weighed, and measured as before. Water lost by evaporation was replaced daily with deionized water.

## RESULTS

The diameter and weight changes, which resulted from the immersion of the cable specimens in the test fluids, are presented in Tables II and III as percentages.

#### Effect of Test Fluids

Neoprene 1. With longer exposure, all N-1 specimens increased in diameter and weight. As the exposure temperatures increased, so did the changes in diameter and weight for corresponding exposure periods. The immersed portion of specimens which had been exposed at 134 F and 175 F or in fluid C were slightly softer than the original material.. All specimens had become more dull in the immersed portion.

\* As given in Table I of ASTM Designation D471-57T



Figure 1. Cable specimens in beaker with test fluid.

Table II. Percent Change in Diameter of Immersed Cable Specimens

Immersion Time (hrs)	Fluid	Temp (F)	N-1	N-2	N-3	N-4	P-1	R-1	V-1
66	A (MIL-R-21006)	Room*	0.49	**	**	**	0.16	-0.28	-0.18
		110	0.60	0.24	-1.05	1.85	0.48	-0.38	-0.25
		134	1.55	1.59	-1.34	2.99	1.44	-0.71	-0.30
		175	3.02	2.80	-2.98	6.99	6.52	-0.64	-0.74
	B (ASTM Oil No. 2)	Room	0.29	**	**	**	0.24	-0.20	-0.01
		110	0.22	-0.19	-1.21	0.81	0.25	-0.46	-0.63
		134	0.74	-0.10	-1.65	1.24	0.75	-1.26	-0.57
		175	1.59	0.98	-2.88	3.95	4.70	-1.75	-0.90
	C (MIL-C-17936)	Room	3.57	**	**	**	0.64	1.87	3.32
		110	6.47	7.25	2.94	14.49	2.51	3.89	3.60
		134	9.10	9.56	3.84	19.59	5.46	7.45	3.47
		175	15.94	18.04	3.09	35.46	Failed	10.70	3.31
130	A (MIL-R-21006)	Room	0.34	-0.13	-0.71	1.09	0.15	-0.24	-0.18
		110	1.16	**	**	2.69	0.69	-0.38	-0.34
		134	2.35	1.71	-1.81	4.04	2.42	-0.80	-0.54
		175	4.57	4.19	-4.15	10.30	8.41	-0.81	-0.95
	B (ASTM Oil No. 2)	Room	0.31	-0.10	-0.58	0.66	0.22	-0.25	-0.29
		110	0.44	**	**	1.21	0.46	-0.71	-0.63
		134	1.12	0.04	-2.19	1.98	1.44	-1.55	-0.68
		175	2.21	1.61	-4.39	5.88	6.24	-2.11	-1.13
	C (MIL-C-17936)	Room	5.11	6.54	2.46	12.54	0.75	2.59	3.80
		110	9.61	10.13	3.64	19.90	3.41	5.65	3.19
		134	14.91	16.55	4.08	30.80	7.60	9.32	3.13
		175	20.07	25.36	1.62	43.72	Failed	13.75	2.54

\* Room temperature: 65-80 F

\*\* No data taken

Note: Values are the average percent change in eight measurements (four on each of two specimens).

Table II. (Cont'd.)

Immersion Time (hrs)	Fluid	Temp (F)	N-1	N-2	N-3	N-4	P-1	R-1	V-1
218	A (MIL-R-21006)	Room*	0.62	0.10	-0.79	1.22	0.10	-0.26	-0.20
		110	1.59	1.08	-1.53	3.50	0.93	-0.49	-0.44
		134	3.30	1.90	-1.99	4.76	3.31	-0.81	-0.68
		175	5.75	4.85	-4.66	12.31	10.11	-0.69	-1.04
	B (ASTM Oil No. 2)	Room	0.56	-0.15	-0.83	0.76	0.24	-0.59	-0.30
		110	0.50	0.15	-1.69	1.37	0.53	-0.89	-0.79
		134	1.30	0.29	-2.48	2.39	1.65	-1.66	-0.80
		175	3.08	2.10	-4.81	6.67	7.78	-2.49	-1.13
	C (MIL-C-17936)	Room	6.85	7.53	3.03	15.01	1.12	3.38	3.98
		110	13.41	**	**	26.92	4.08	7.83	3.07
		134	17.45	18.61	3.76	35.34	8.58	11.29	2.38
		175	22.76	27.93	1.54	45.56	Failed	16.26	2.19
300	A (MIL-R-21006)	Room	0.55	0.30	-0.81	1.32	0.32	-0.35	-0.26
		110	1.94	1.83	-2.29	3.75	1.03	-0.49	-0.58
		134	3.94	2.29	-2.22	5.49	3.76	-0.71	-0.70
		175	6.61	5.70	-5.20	14.82	10.48	-0.36	-1.10
	B (ASTM Oil No. 2)	Room	0.47	0.01	-1.04	0.78	0.26	-0.38	-0.35
		110	0.65	0.44	-2.55	1.62	0.58	-0.92	-0.84
		134	1.50	0.26	-2.61	2.71	2.15	-1.72	-1.01
		175	3.64	2.60	-5.31	8.24	9.09	-2.55	-1.21
	C (MIL-C-17936)	Room	7.65	8.70	3.29	17.04	1.51	4.06	3.71
		110	14.25	18.09	2.85	28.75	4.30	8.64	2.56
		134	18.35	20.40	3.75	39.06	9.14	11.55	1.90
		175	23.41	30.31	1.26	47.82	Failed	17.66	2.03

\* Room temperature: 65-80 F

\*\* No data taken

Note: Values are the average percent change in eight measurements (four on each of two specimens).

Table III. Percent Change in Weight of Immersed Cable Specimens

Immersion Time (hrs)	Fluid	Temp (F)	N-1	N-2	N-3	N-4	P-1	R-1	V-1
66	A (MIL-R-21006)	Room*	0.07	0.16	-0.28	0.26	-0.04	-0.10	-0.05
		110	0.46	0.30	-0.52	0.75	0.31	-0.13	-0.15
		134	0.80	0.40	-0.85	1.31	0.68	-0.37	-0.20
		175	1.50	1.11	-1.69	3.68	3.38	-0.57	-0.44
	B (ASTM Oil No. 2)	Room	-0.04	0.07	-0.29	0.02	-0.03	-0.16	-0.04
		110	0.16	0.05	-0.63	0.38	0.23	-0.20	-0.19
		134	0.30	0.02	-0.95	0.63	0.45	-0.59	-0.25
		175	0.81	0.29	-1.95	2.00	2.69	-0.89	-0.64
	C (MIL-C-17936)	Room	1.73	1.88	1.00	3.80	0.34	0.58	0.89
		110	3.71	3.56	2.22	6.09	1.62	1.62	1.47
		134	5.08	5.11	3.84	10.58	3.54	2.37	2.67
		175	9.63	8.33	3.14	20.23	Failed	4.43	2.85
130	A (MIL-R-21006)	Room	0.14	0.22	-0.38	0.45	0.02	-0.11	-0.13
		110	0.64	0.50	-0.73	1.19	0.37	-0.31	-0.20
		134	1.23	0.67	-1.03	2.01	1.33	-0.41	-0.29
		175	2.22	1.87	-2.43	5.60	4.53	-0.61	-0.62
	B (ASTM Oil No. 2)	Room	0.01	0.09	-0.42	0.13	-0.05	-0.22	-0.10
		110	0.22	0.17	-0.82	0.60	0.27	-0.31	-0.28
		134	0.31	0.13	-1.19	1.05	0.77	-0.66	-0.36
		175	1.18	0.69	-2.80	3.10	3.59	-1.14	-0.81
	C (MIL-C-17936)	Room	2.31	2.76	1.50	5.84	0.50	0.82	1.20
		110	5.41	4.88	2.73	8.57	2.27	2.38	2.09
		134	7.56	7.14	4.08	16.59	5.23	3.42	3.10
		175	12.46	12.68	2.72	27.90	Failed	5.46	2.76

\* Room temperature: 65-80 F

Note: Values are the average percent change in weight of two specimens.

Table III (Cont'd.)

Immersion Time (hrs)	Fluid	Temp (F)	N-1	N-2	N-3	N-4	P-1	R-1	V-1
218	A (MIL-R-21006)	Room*	0.19	0.27	-0.42	0.56	0.08	-0.14	-0.10
		110	0.93	0.57	-0.86	1.67	0.56	-0.25	-0.26
		134	1.69	0.79	-1.15	2.38	2.01	-0.46	-0.38
		175	2.96	2.27	-2.77	6.70	7.32	-0.54	-0.78
	B (ASTM Oil No. 2)	Room	0.02	0.10	-0.45	0.17	-0.04	-0.24	-0.11
		110	0.36	0.17	-0.99	0.84	0.37	-0.25	-0.39
		134	0.61	0.18	-1.40	1.25	1.05	-0.71	-0.46
		175	1.64	0.90	-3.20	3.69	4.54	-1.27	-1.10
	C (MIL-C-17936)	Room	3.47	3.25	1.80	6.94	0.64	1.12	1.46
		110	7.79	5.84	2.99	11.47	3.13	3.41	2.56
		134	9.32	8.35	3.76	19.63	5.94	3.82	2.95
		175	14.27	14.48	2.45	30.52	Failed	6.71	2.13
300	A (MIL-R-21006)	Room	0.30	0.31	-0.45	0.68	0.14	-0.10	-0.15
		110	1.03	0.87	-1.31	1.79	0.65	-0.28	-0.20
		134	2.02	0.92	-1.32	2.76	2.32	-0.46	-0.37
		175	3.57	2.73	-3.11	7.95	8.91	-0.42	-0.84
	B (ASTM Oil No. 2)	Room	0.03	0.11	-0.46	0.25	0.05	-0.17	-0.09
		110	0.39	0.26	-1.41	0.92	0.45	-0.39	-0.32
		134	0.74	0.23	-1.56	1.46	1.24	-0.81	-0.47
		175	2.01	1.14	-3.57	4.46	7.23	-1.25	-1.21
	C (MIL-C-17936)	Room	4.26	3.74	2.09	8.08	0.89	1.51	1.63
		110	8.44	7.87	2.79	12.13	3.34	3.63	2.46
		134	10.17	9.04	3.75	22.22	6.43	4.04	2.62
		175	15.18	16.24	2.40	31.05	Failed	7.45	1.77

\* Room temperature: 65-80 F

Note: Values are the average percent change in weight of two specimens

Neoprene 2. When N-2 specimens were immersed in fluids A and B at room temperature the material decreased in diameter during the initial exposure period. During subsequent exposure periods this shrinkage stopped, and the specimens expanded to a point just above the original diameter. This phenomenon of shrinkage followed by expansion was repeated for N-2 specimens immersed in fluid B at 110 F and 134 F, but not at 175 F. Specimens of N-2 immersed in fluid A at other than ambient temperatures did not show this phenomenon, nor did any of the specimens of N-2 immersed in fluid C.

Weight measurements indicate absorption of all three fluids by the test specimens, increasing at higher temperatures or with longer exposure. The specimens had developed a diamond-shaped surface texture in the immersed portions. This was particularly noticeable on specimens which had been immersed at 175 F or in fluid C.

Neoprene 3. All specimens of N-3 immersed in fluids A and B decreased in both diameter and weight. Specimens immersed in fluid C at room temperature increased in both diameter and weight, and continued to increase until the final measurements were taken. Immersion in fluid C at other temperatures produced increases in diameter and weight to maxima followed by decreases. At 110 F the maxima in diameter and weight were recorded at different exposure intervals, while at 134 F and 175 F the greatest values were measured at the same time.

The immersed section of the specimens had become quite hard; thumbnail pressure had no effect. Some resiliency remained, however, in the unimmersed portions. The jackets of the specimens of N-3 immersed in fluid C at 175 F shrank an average of 7/16 inch, about 5 percent of a length of 8-7/8 inches. A spiral contour developed in the specimens which had been immersed in fluid C. The immersed portions were blacker than the original material.

Neoprene 4. Specimens of N-4 increased both in diameter and weight when immersed in any of the test fluids. The diameters and weights continued to increase with longer exposure, and for the same length of exposure were greater at higher temperatures. The specimens had become soft in the immersed portion. Specimens which had been immersed in fluid C were softer than those immersed in fluid B; they in turn were softer than those immersed in fluid A. The immersed portion had less shine than the original material.

Polyethylene. All specimens of P-1 increased in diameter and weight regardless of temperature. The specimens immersed in fluid C at 175 F had completely failed during the first 66 hours. The insulation had separated from the conductor over all of the immersed portion of the specimen; only the unimmersed portion remained undamaged. It was noted that the lost material, which had settled to the bottom of the beaker, and lower ends of the portions still adhering to the conductor were split into strips running lengthwise of the specimen. The specimens immersed in fluids A and B at 175 F had split at the bottom of the "U" by the end of the test period, but the material had not completely separated. The splitting was not evidenced at any other temperature. No other changes in the specimens were noted.

Butadiene-Acrylonitrile. Specimens of R-1 were not uniform in their reactions to the three test fluids. Those specimens immersed in fluids A and B showed a decrease in diameter and a loss of weight, while those immersed in fluid C showed an increase in diameter and a gain of weight. The specimens immersed in fluid A at room temperature and 110 F shrank continuously during the test, while their weights reached a low point and began to increase. The 134 F specimens decreased in diameter until the last exposure interval, when they began to expand; the weight loss was continuous during the entire test. The specimens immersed at 175 F decreased both in diameter and weight during the first two exposure periods; during the last two periods they began to increase, but did not reach their original sizes and weights. Specimens which had been immersed in fluid C at 175 F were softer in the immersed portion. This area became darker for specimens immersed in fluid C at all temperatures, and was true also for specimens immersed in the other fluids at 175 F.

Polyvinyl Chloride. Specimens of V-1 immersed in fluids A and B generally decreased in diameter and weight with longer exposure and increasing temperature. However, the 110 F series in both fluids indicate a slight gain in weight during the final exposure period which was not accompanied by a corresponding change in diameter.

Data on the specimens immersed in fluid C indicate increases to a maximum followed by decreases in weight and diameter. This pattern was indicated by all sets of data except for the change in weight at room temperature; no maximum was attained during this exposure. Generally the maximum values for different temperatures were obtained earlier with higher temperatures. However, the maxima in diameter and weight for the same specimens were not measured after the same period.

At the end of the exposure period, the specimens immersed in fluid C at 134 F displayed a jacket shrinkage of  $3/16$  inch in length, while the insulation layer had increased  $1/8$  inch in length. After 300 hours at 175 F, jackets of the specimens in fluid A had shrunk  $1/4$  inch in length, while those in fluid B had shrunk  $3/8$  inch; no change was noted in the length of the insulation. The jackets of specimens immersed in fluid C at 175 F shrank  $11/16$  inch (8 percent) in length, and the insulation expanded about  $5/8$  inch (7 percent) in length. The specimens were approximately  $8\text{--}1/2$  inch long. Specimens which had been immersed in fluid C became discolored in the immersed portion.

#### Effect of Sea Water

In determining the effect of sea water on the specimens, only the weight measurements were considered. The diameter measurements varied only a little from the trend established by the weights. The percent changes indicated in the following paragraphs, then, are based on the weights of specimens prior to the beginning of the water immersion.

All neoprene specimens previously immersed in fluid A at room temperature or 175 F continued to change in the same direction when immersed in sea water; that is, if they had been increasing in weight they continued to do so; if they had been decreasing in weight they decreased further when immersed in sea water. The specimens previously immersed in fluid C exhibited an opposite behavior; all specimens had increased in weight when immersed in the test fluid, but lost weight when placed in sea water. The percent changes in these and the previously unexposed specimens are shown in Table IV.

The specimens of polyethylene which had been immersed in the test fluids at 175 F failed under test as described. The specimens from the test at 134 F were substituted for them in the sea-water immersion. The final results of the immersion of the room temperature and 134 F specimens at room temperature and 175 F respectively in sea water are given in Table IV.

Specimens of R-1 which had lost weight when immersed in fluid A increased in weight when immersed in sea water. The specimens which had increased appreciably in weight when immersed in fluid C decreased slightly when immersed in sea water.

Immersion in sea water of specimens of V-1 which previously had been immersed in fluid A showed little change from the effects of the first immersion. The specimens of V-1 previously immersed in fluid C at room temperature lost about half the original increase when immersed in sea water; immersion of specimens in sea water at 175 F resulted in the loss of the weight gained during the earlier immersion in fluid C. New specimens, when immersed in sea water, changed very slightly from the original weight.

## DISCUSSION

Of the materials tested, specimens with sheaths of polyvinyl chloride or of the butadiene-acrylonitrile copolymer were least affected by action of the various fluids used. The shrinking of the PVC sheath and accompanying expansion of the polyethylene insulation occurred either in test fluid C or at 175 F. Fluid C is no longer authorized for use, and the high temperature probably would not be encountered in actual service, so this sheath-insulation system is considered satisfactory.

If data from the extreme exposure conditions are not considered, (fluid C or 175 F) the order in decreasing resistance of the other materials is N-2, P-1, N-1, N-3, N-4. The same order holds if the higher temperature is considered, but if fluid C is considered as well, N-1 goes from third position to first.

The use of two-component flotation-type corrosion inhibitors in ballast tanks has resulted in a number of cases of dermatitis among personnel whose duties took them into the tanks. For example, the inhibitor (fluid C) used in this test is known to contain an appreciable amount of cresylic acid, which can cause dermatitis. As a result, the specification for two-component inhibitor materials (MIL-C-17936) has been superseded by a specification (MIL-R-21006) for single-component materials. Since both fluids were still used when this study was initiated both were included for comparison of their effect on cable sheaths.

Table IV. Percent Change in Weight of Specimens When Immersed in Sea Water for 315 Hours

Material	Temperature (F)	Previous Immersion		
		MIL-R-21006	MIL-C-17936	None
N-1 <sup>1</sup>	Room*	0.23	-0.30	0.22
	175	1.03	-0.40	1.03
N-2 <sup>2</sup>	Room	0.15	-0.02	No Data
	175	0.48	-2.35	
N-3 <sup>2</sup>	Room	-0.11	-0.13	No Data
	175	-0.03	-1.79	
N-4 <sup>2</sup>	Room	0.15	-0.13	0.26
	175	1.20	-5.45	2.63
P-1 <sup>1</sup>	Room	0.19	-0.02	0.12
	134	-0.27	-0.82	0.07
R-1 <sup>1</sup>	Room	0.34	-0.05	0.50
	175	1.27	-0.32	1.05
V-1 <sup>2</sup>	Room	-0.05	-0.84	-0.03
	175	-0.07	-1.89	0.02

\* Room temperature: 65-80 F

1. Values are for single specimens.

2. Values are average percent change of two specimens.

This study was concerned only with the effect of flotation-type corrosion inhibitors on the sheath materials. No attempt has been made to determine the results of employing the cables tested in either galvanic or impressed current cathodic protection systems concurrently with these floating corrosion inhibitors.

As long as steel floating dry docks are used, steps must be taken to protect the interiors of ballast compartments. This may be cathodic protection, or the application of some type of corrosion inhibitor or both. When both are to be used, connecting cables must be selected which will resist the effects of the floating corrosion inhibitor.

## FINDINGS

Based on 300 hours of immersion:

1. The butadiene-acrylonitrile copolymer sheath was the most resistant to the effects of the test fluids.
2. The polyvinyl chloride sheath was not as resistant to the effects of fluid C as was the butadiene-acrylonitrile copolymer, but otherwise is its equal or superior.
3. Navy stock neoprene sheaths or polyethylene are acceptable if the environment will not include two-component flotation-type corrosion inhibitors or high temperatures.

## CONCLUSIONS

Based on 300 hours of specimen immersion:

1. ASTM Oil No. 2 is not satisfactory for use as a standard fluid in the accelerated evaluation of the resistance of cable sheaths to the effects of flotation-type corrosion inhibitors.
2. Acceptance tests of cables should include immersion in corrosion inhibitors which may be used in conjunction with cathodic protection systems.

## RECOMMENDATIONS

1. That sheaths of polyvinyl chloride or butadiene-acrylonitrile be specified for cables in floating dry-dock ballast tanks where high temperatures are anticipated.
2. That Navy stock neoprene be used if moderate temperatures only are anticipated and no two-component inhibitors are used.
3. That samples of cables be tested in corrosion inhibitors prior to their combined use.

## Appendix A

### DESCRIPTION OF TEST CABLES

All of the cables described below are 600-volt cables, with the exception of R-1.

#### Neoprenes

N-1 is a commercial No. 4 cable, and consists of a multi-stranded single conductor, a fine thread wrapping, a 5/64-inch layer of butyl rubber insulation, and 5/64-inch-thick neoprene sheath. The surface is dull and smooth, except for the manufacturer's impressed markings. The overall diameter is 9/16 inch.

N-2 is also a No. 4 cable, but was obtained from Navy stock. It consists of a multi-stranded single conductor, a paper separator, a 5/64-inch insulation layer of butyl rubber, a wide-spaced weaving of cotton thread, and a 5/64-inch neoprene sheath. The surface is dull and smooth, with no external markings. The overall diameter is 9/16 inch.

N-3, also obtained from Navy stock, is a multi-stranded single-conductor No. 6 cable. Around the conductor is wrapped a thin, flexible transparent material, followed by a 3/64-inch layer of butyl rubber, a winding of four equally-spaced threads, and a 5/64-inch neoprene sheath. Both the butyl insulation and the neoprene sheath seemed softer than the same layers of N-1 and N-2. The exterior surface was smooth, shiny, and unmarked. The overall diameter is 7/16 inch.

N-4, another commercial product, is also a No. 6 cable. It consists of a seven-stranded, tinned, single conductor, a 1/16-inch layer of butyl rubber insulation, and a 1/16-inch-thick neoprene sheath. The butyl and neoprene were fairly well vulcanized together, which was not true with the other three neoprenes. The exterior is smooth, has a slight shine and bears the manufacturer's printed identification. The overall diameter is 7/16 inch.

#### Polyethylene

P-1 is a commercial No. 6 cable consisting of a seven-strand single conductor, and a 1/8-inch-thick layer of polyethylene which serves both as insulator and sheath. The outer surface is smooth, has a slight shine, feels waxy, and bears the manufacturer's printed identification. The overall diameter is 13/32 inch.

#### Polyvinyl Chloride

V-1 is a commercial No. 6 cable consisting of a seven-strand single conductor, a 1/16-inch-thick insulation layer of polyethylene, and a 3/64-inch-thick polyvinyl chloride sheath. The outer surface is smooth, shiny, and bears the manufacturer's printed identification. The overall diameter is 13/32 inch.

## Butadiene-acrylonitrile

R-1 is the only sample tested which is not a standard 600-volt cable. It is a coated solid-copper conductor about  $5/32$  inches in diameter, insulated by a  $1/16$ -inch layer of neoprene and jacketed with a  $1/32$ -inch layer of a butadiene-acrylonitrile copolymer. The exterior surface has a slight sheen and is covered by very small irregularities. The overall diameter is  $11/32$  inch.

Appendix B

CHANGES IN DIAMETERS OF CABLE SPECIMENS  
AFTER IMMERSION IN FLOATING CORROSION INHIBITORS

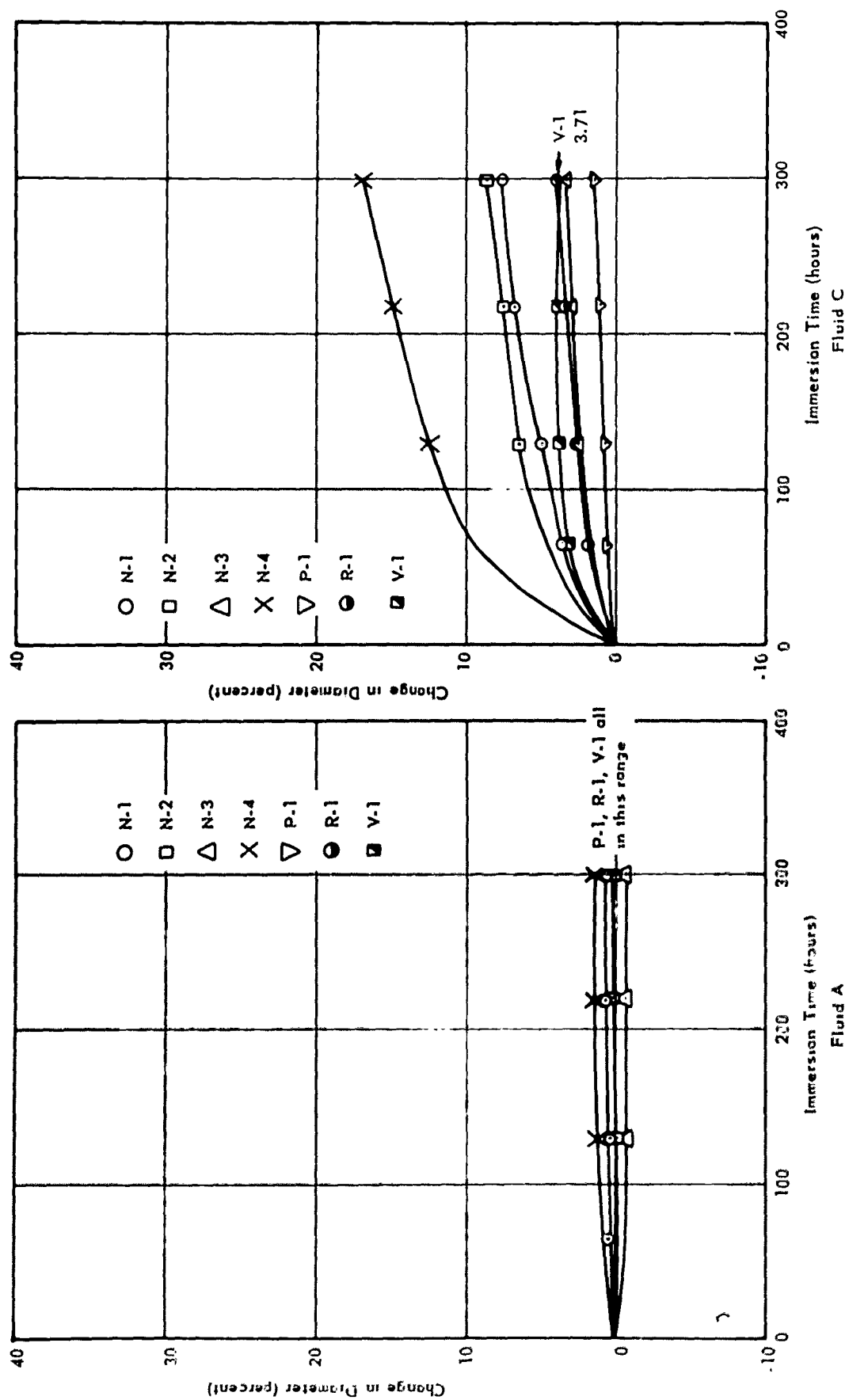


Figure 2. Effect on cable sheaths of immersion in floating inhibitors at room temperature.

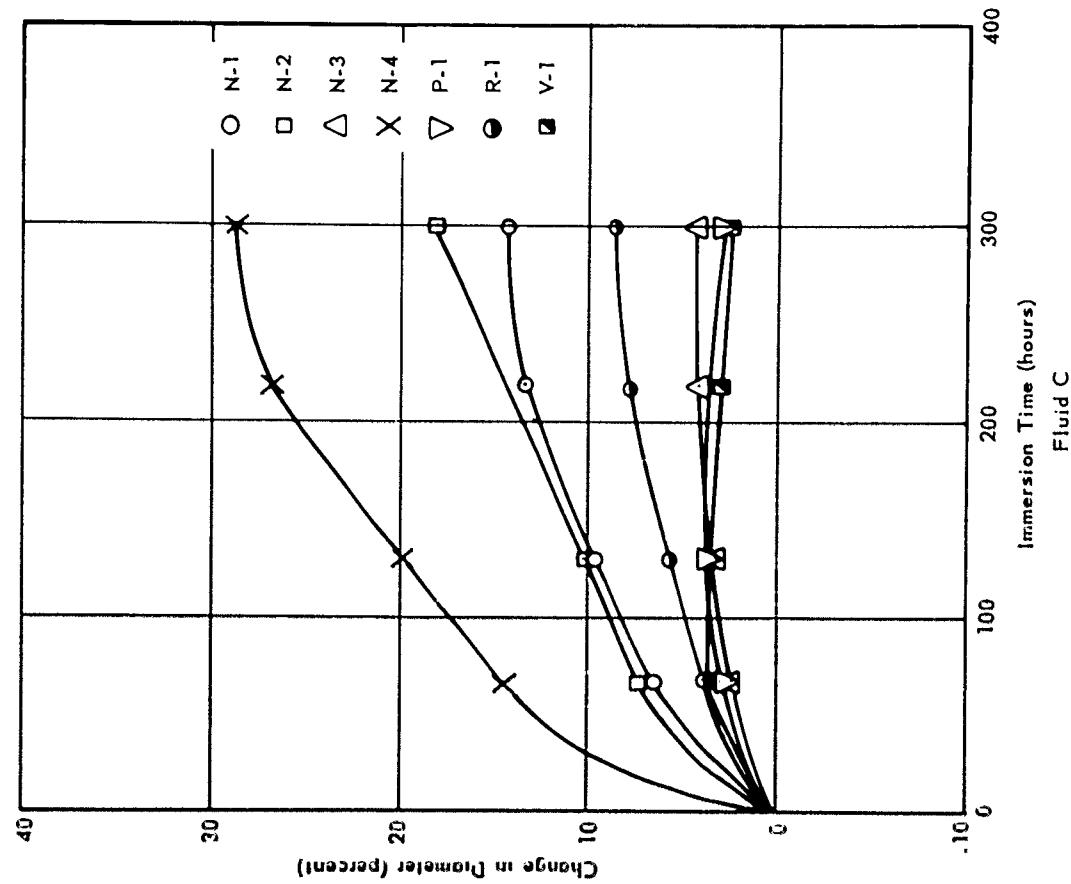
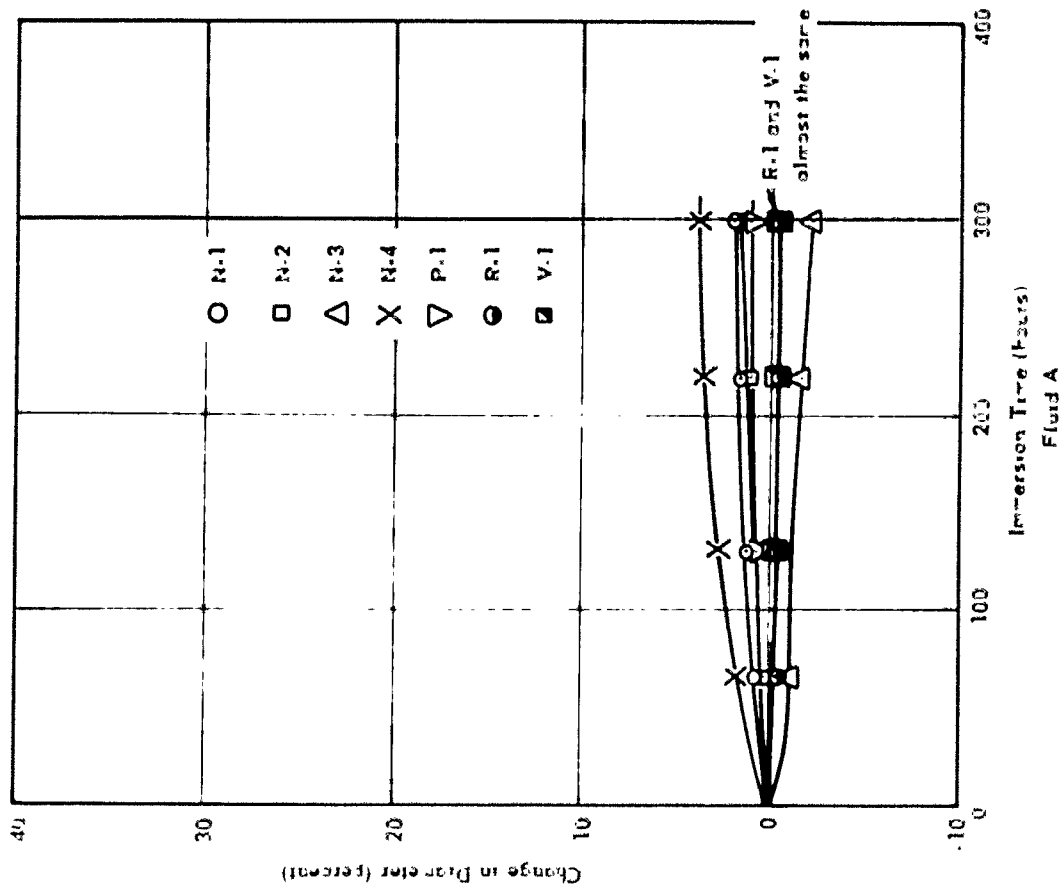


Figure 3. Effect on cable sheaths of immersion in floating inhibitors at 110 F.

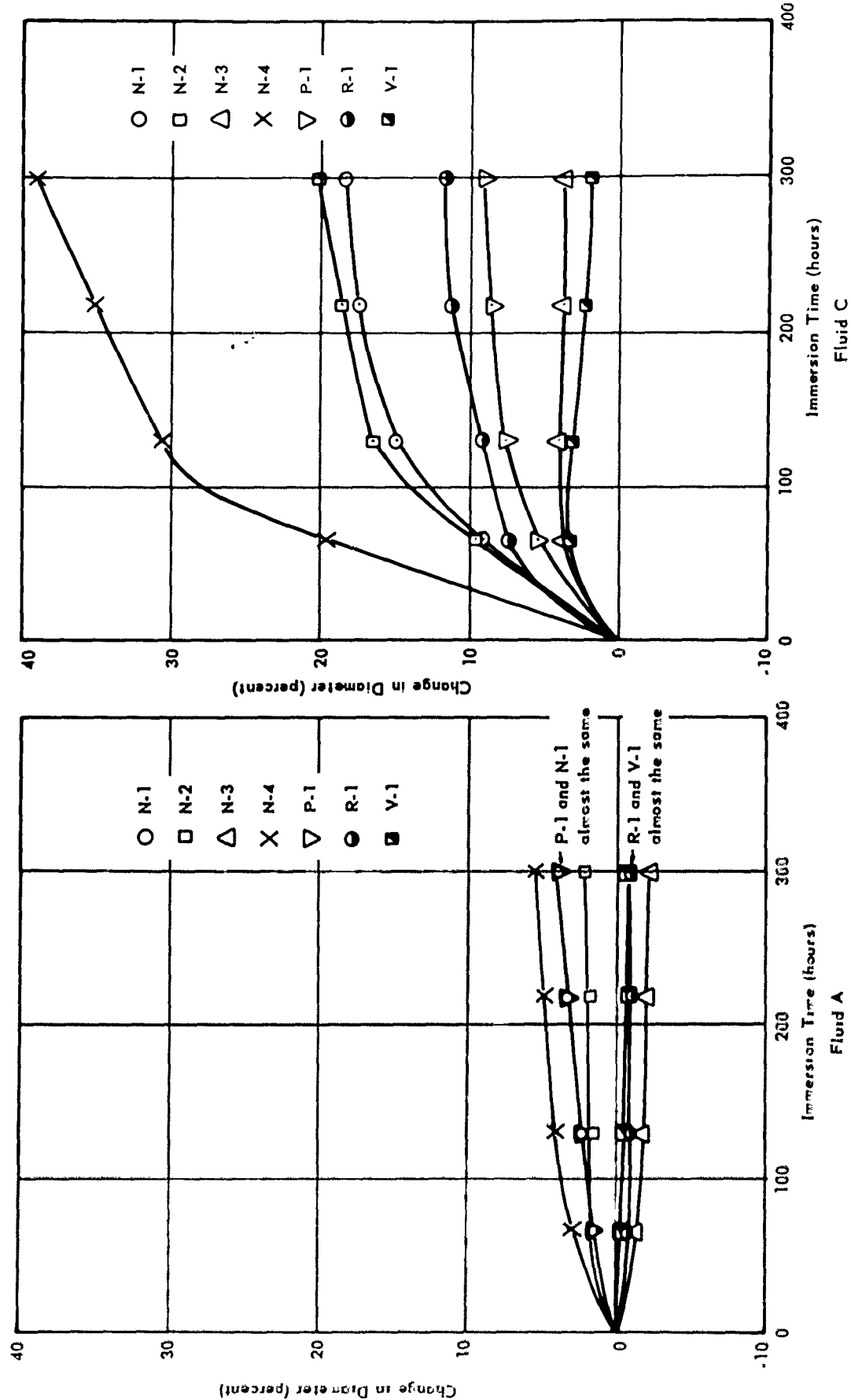


Figure 4. Effect on cable sheaths of immersion in floating inhibitors at 134 F.

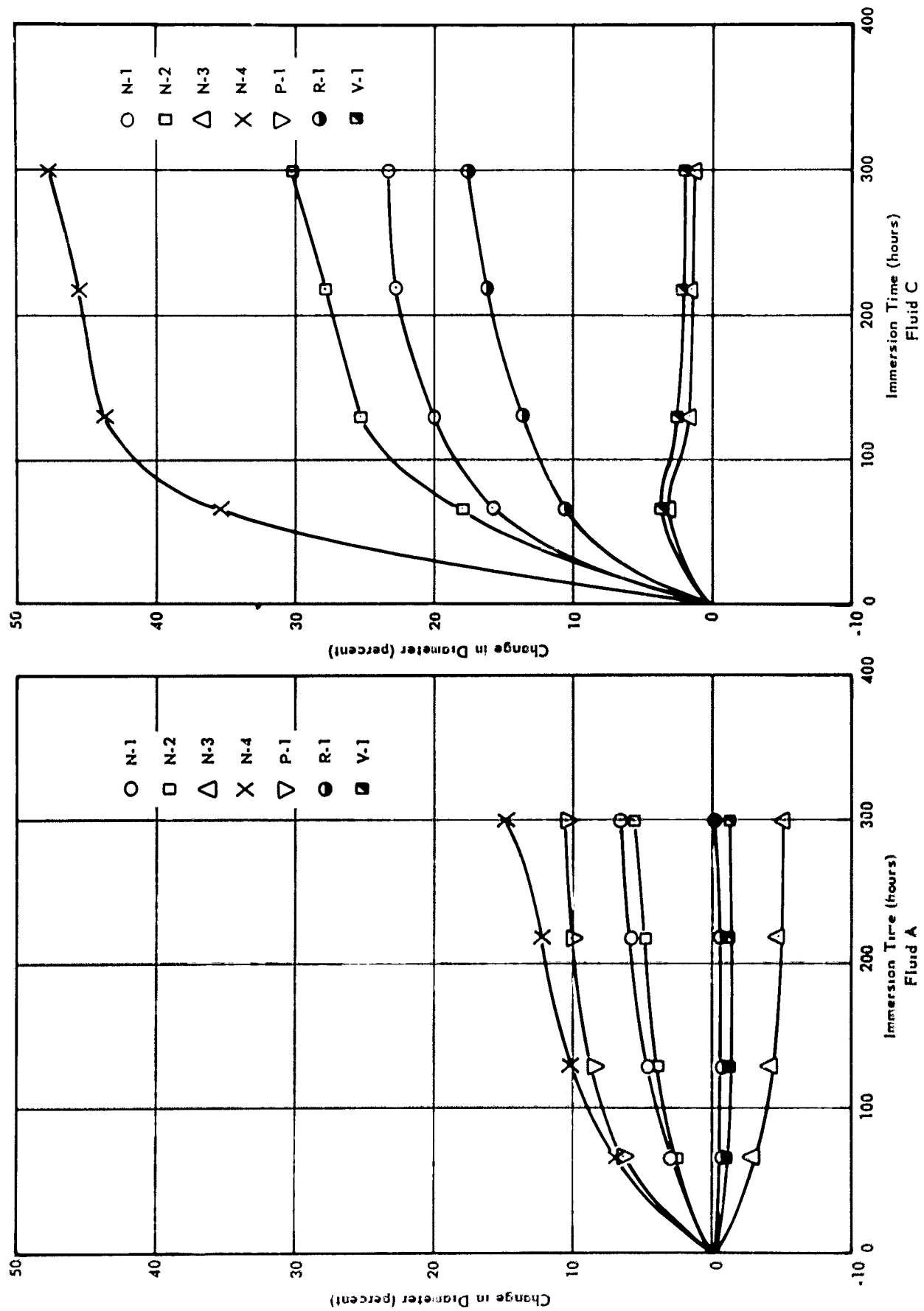


Figure 5. Effect on cable sheaths of immersion in floating inhibitors at 175 F.

Appendix C

CHANGES IN WEIGHT OF CABLE SPECIMENS  
AFTER IMMERSION IN FLOATING CORROSION INHIBITORS

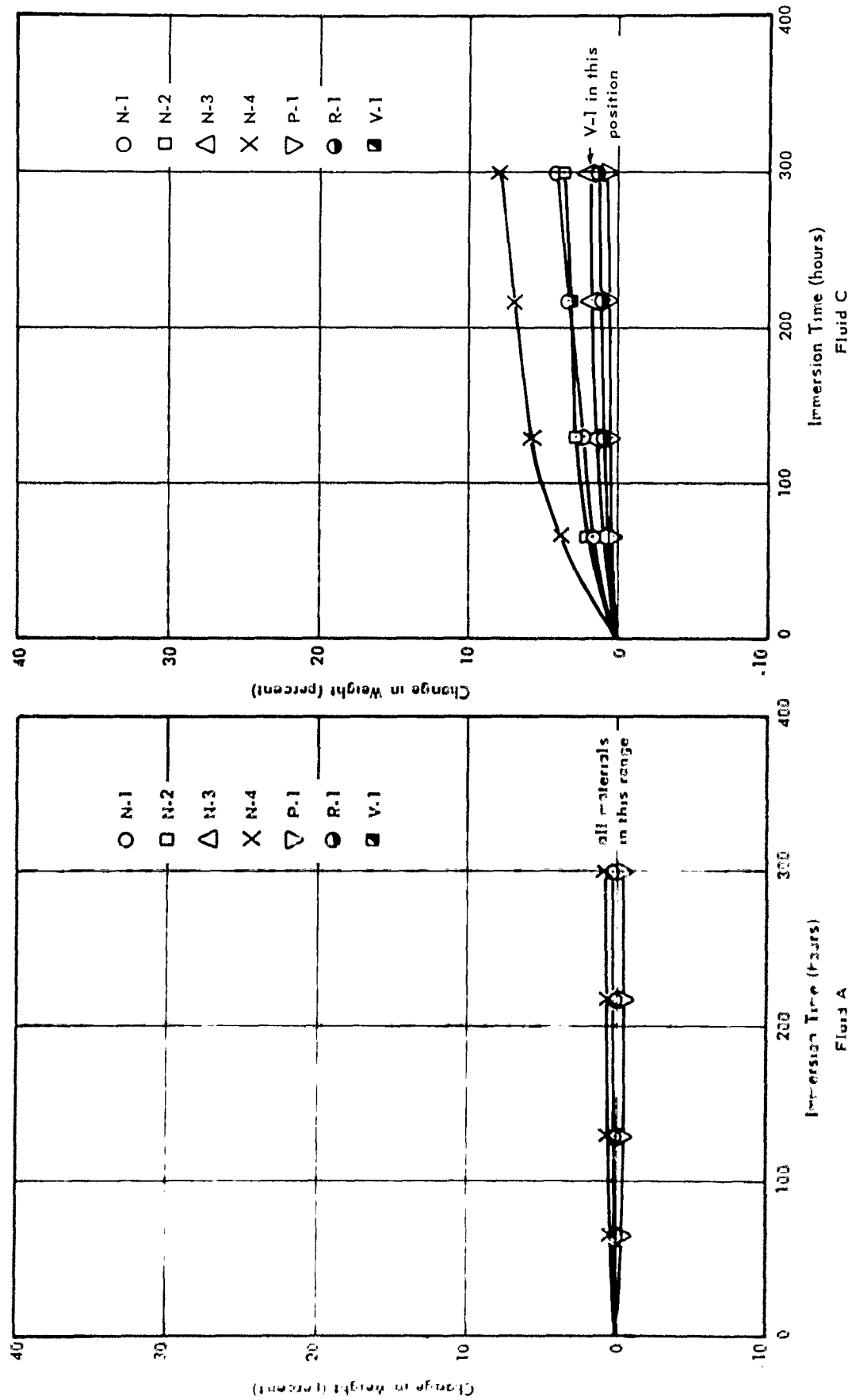


Figure 6. Effect on cable sheaths of immersion in floating inhibitors at room temperature.

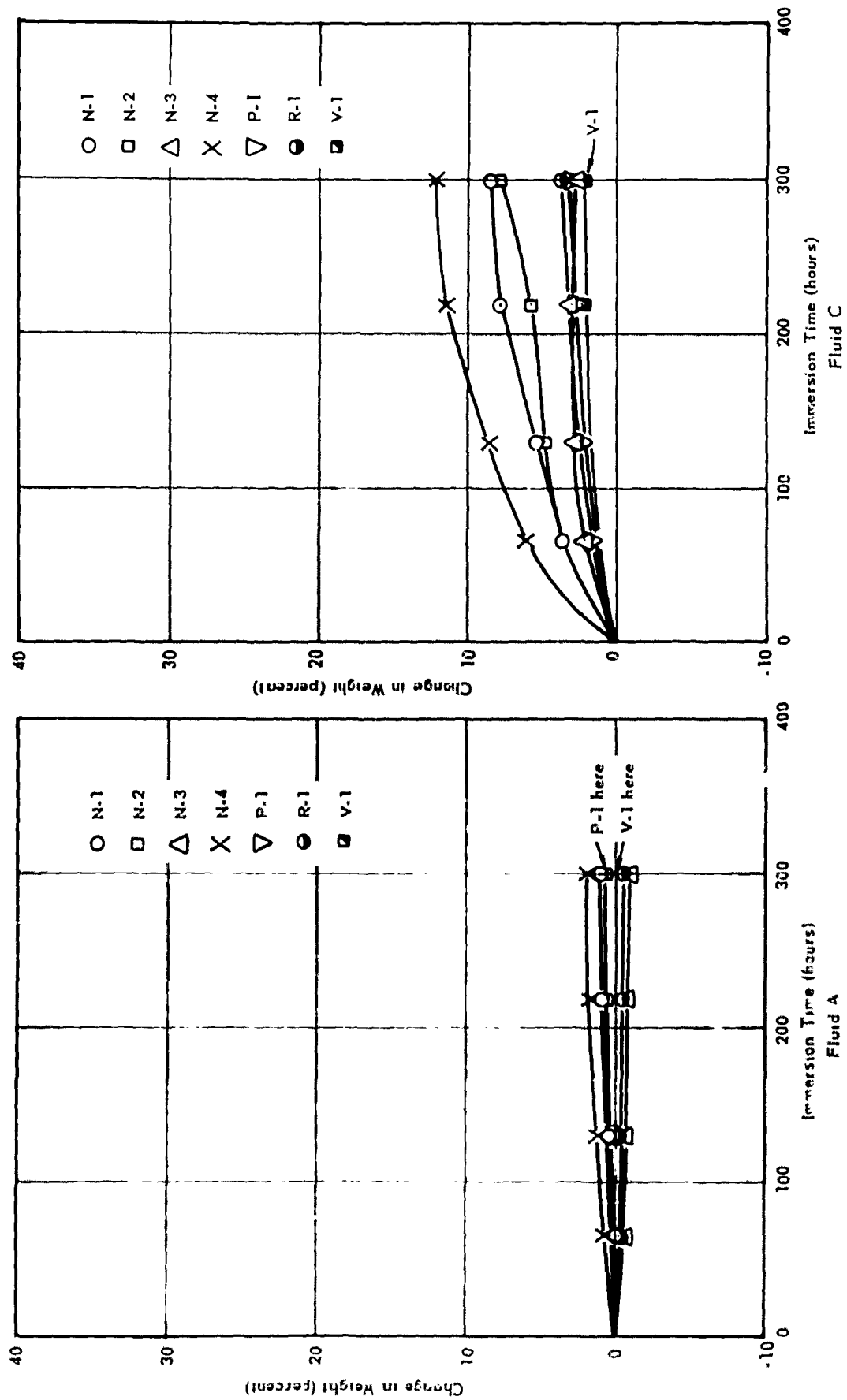


Figure 7. Effect on cable sheaths of immersion in floating inhibitors at 110 F.

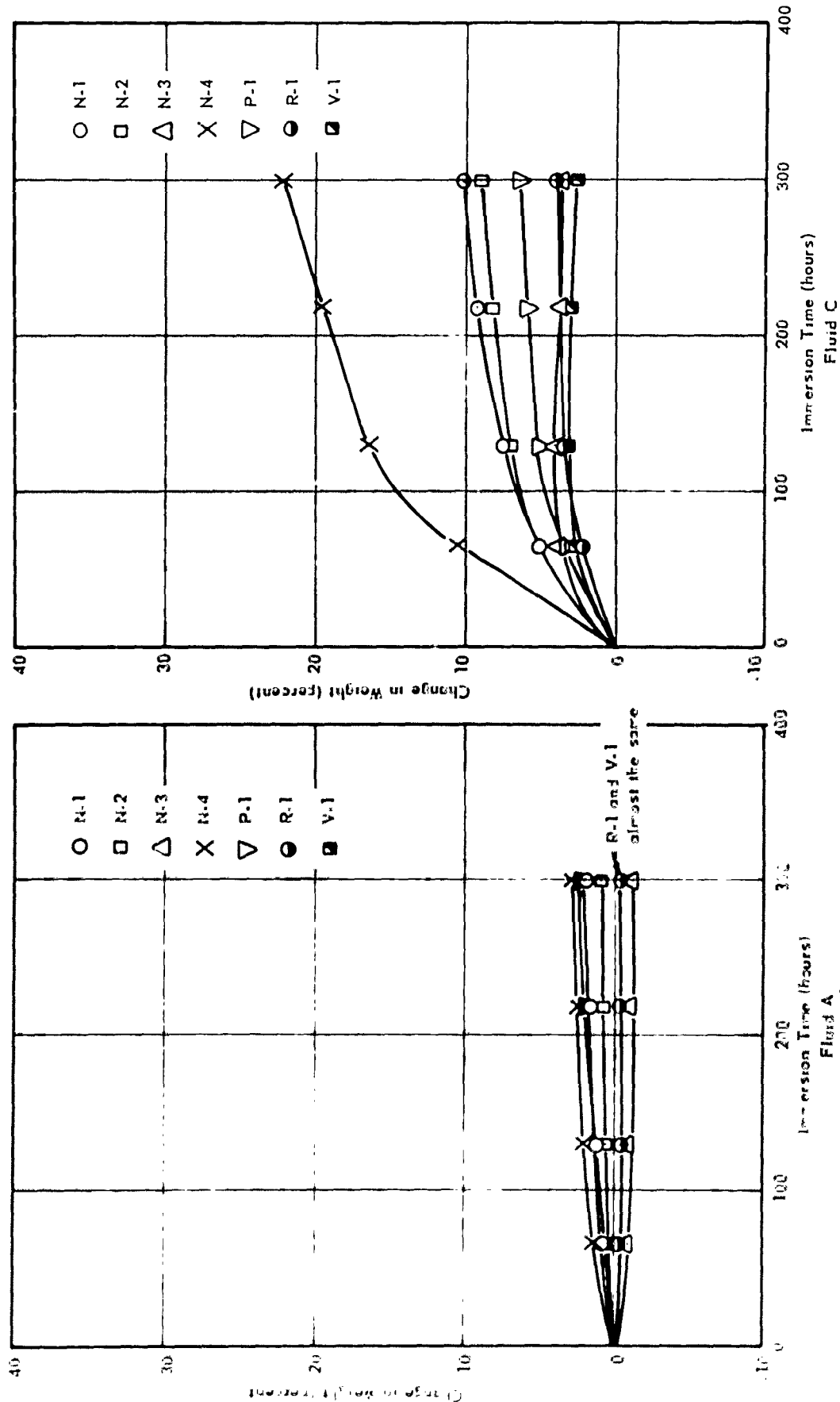


Figure 8. Effect on cable sheaths of immersion in floating inhibitors at 134 F.

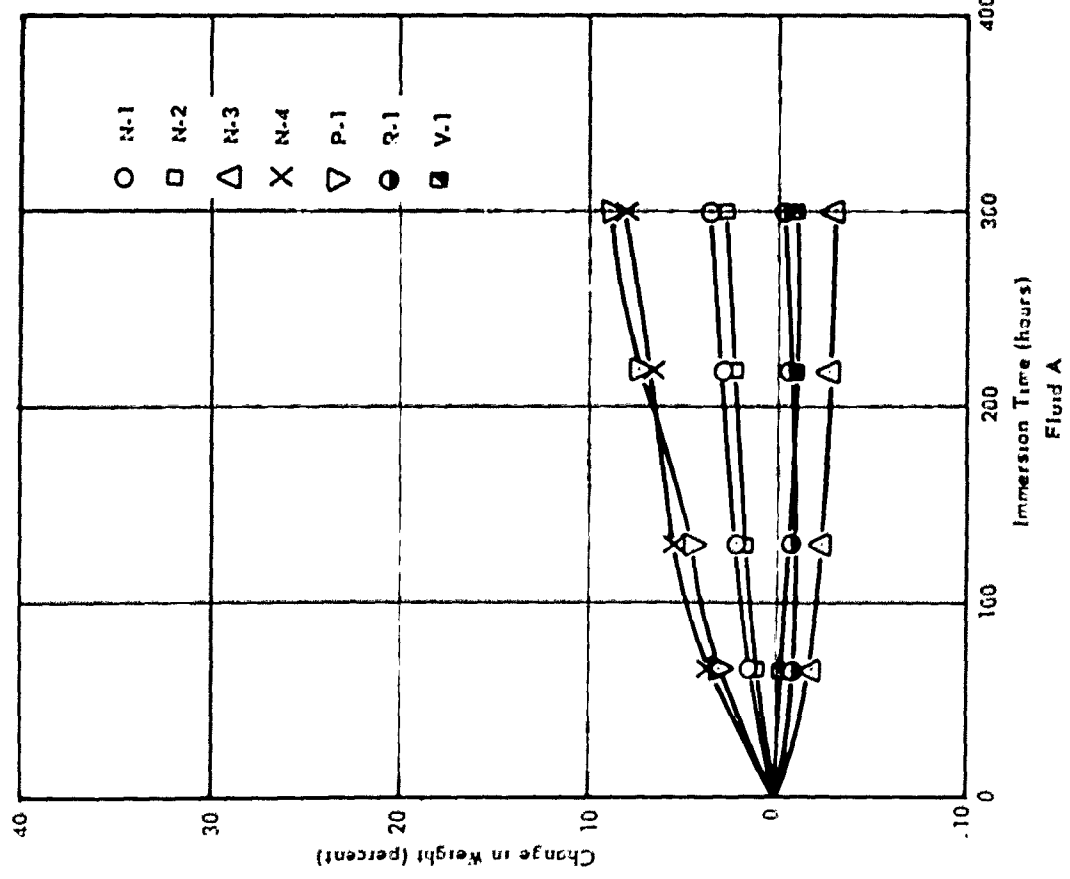
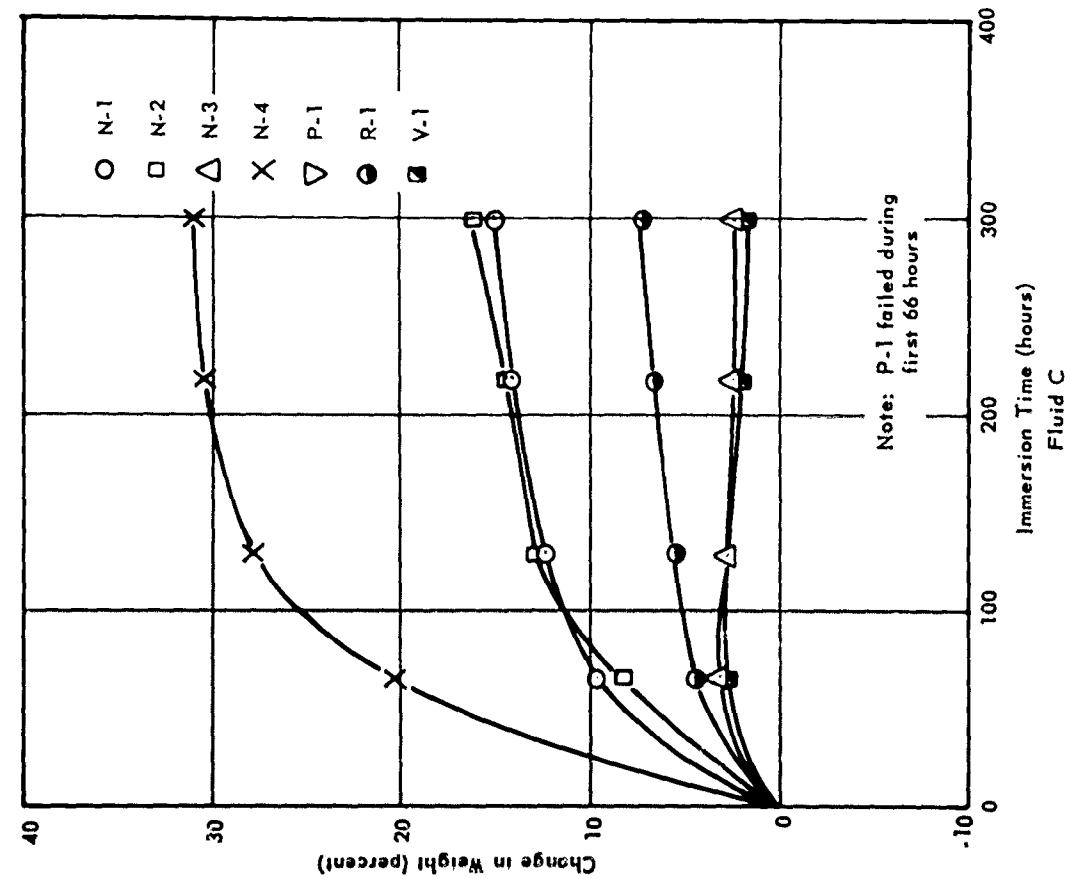


Figure 9. Effect on cable sheaths of immersion in floating inhibitors at 175 F.

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